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Solid Waste Collection Robot

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ABSTRACT

With rapid urbanization and increasing population density, solid waste management has become a pressing challenge in modern cities. Traditional waste collection systems are often inefficient and pose health risks due to direct human involvement. To address this, we propose a web-operated solid waste collection robot designed to assist in efficient and hygienic waste handling. The robot is built around the ESP32- WROOM microcontroller and is equipped with DC motors, servo motors, and an L298N motor driver to control movement and mechanical functions. The system is operated remotely through a custom web interface, allowing the user to navigate the robot and control its robotic arm for picking up and disposing of waste. The robot uses basic sensor inputs for object detection and obstacle avoidance, improving operational ease in varied environments. This approach reduces the need for human interaction in waste-heavy areas, making the system a practical, costeffective, and scalable solution for improving urban sanitation.

INTRODUCTION

Waste management has become a significant concern in urban areas due to rapid population growth and increased waste generation. Traditional collection methods are often manual, time- consuming, and expose workers to hazardous conditions. These systems also struggle to meet the growing demand for cleanliness and efficiency. With the advancement of technology, particularly in the fields of the Internet of Things (IoT) and robotics, new possibilities have emerged for automating waste collection processes. These smart systems can not only reduce human intervention but also improve response times, optimize operations, and promote a cleaner environment.

Existing waste collection systems are largely inefficient and labor-intensive, often resulting in uncollected waste, high operational costs, and health risks to workers. There is a lack of automation and real-time control in the current systems, which limits their effectiveness in dynamic urban environments. To address these challenges, this project proposes the development of a web-operated solid waste collection robot that integrates IoT for remote control and monitoring, improving both safety and efficiency in waste management.

The objectives of this project are to design and develop a web-controlled solid waste collection robot, integrate IoT to enable realtime operation and monitoring, reduce human involvement in hazardous waste collection environments, optimize energy consumption, and improve accuracy and reliability in garbage handling and disposal.

LITERATURE REVIEW

Effective solid waste management has become a pressing concern due to the rapid growth of urban populations and increasing waste generation. Traditional waste collection systems are manual, laborintensive, and often inefficient, researchers have increasingly turned to automation, robotics, and IoT-based technologies to modernize waste handling systems.
Various studies have explored the use of autonomous robots equipped with sensors, microcontrollers, and wireless modules for waste detection and collection. Some designs focus on autonomous path planning and navigation using ultrasonic or infrared sensors for obstacle avoidance. Others employ robotic arms with servo motors to collect solid waste items. These systems aim to reduce human involvement and improve operational safety and accuracy.

Projects utilizing ESP32 or similar microcontrollers have demonstrated the potential of integrating IoT for remote control and real-time monitoring. Wireless connectivity allows for mobile or web-based interfaces, enhancing accessibility and ease of use. Several researchers have also implemented image processing and machine learning techniques for object detection and

waste classification, though such systems may require high computational resources. Despite these innovations, many existing systems either lack scalability or involve high costs. Our project builds upon this foundation by introducing a mobile-controlled, costefficient robot capable of navigating, collecting, and sorting waste. It uses ESP32WROOM for wireless control, gear motors for mobility, and servo-driven claws for waste handling. The system is designed to offer real-time responsiveness, reduced human intervention, and suitability for deployment in urban environments.

METHODOLOGY

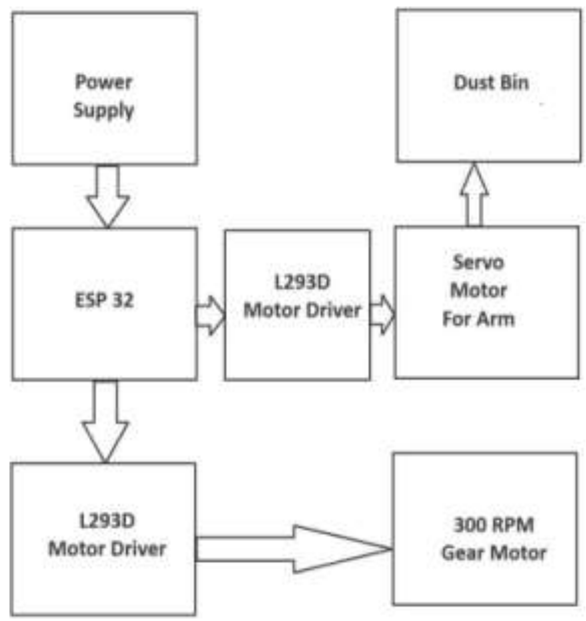


Fig. Block Diagram

The proposed system is developed to facilitate efficient, contactless solid waste collection through a mobile-controlled robotic platform. This methodology integrates both hardware and software components to enable robot navigation, arm control for waste handling, and power management. The complete system workflow is represented in the block diagram, which illustrates the interconnection between all modules.

At the core of the system is the ESP32WROOM microcontroller, which serves as the central controller. It receives input commands via a web interface hosted on the ESP32 itself, allowing remote control through any browser-enabled device. The ESP32 processes these commands to control motor direction and robotic arm movements.

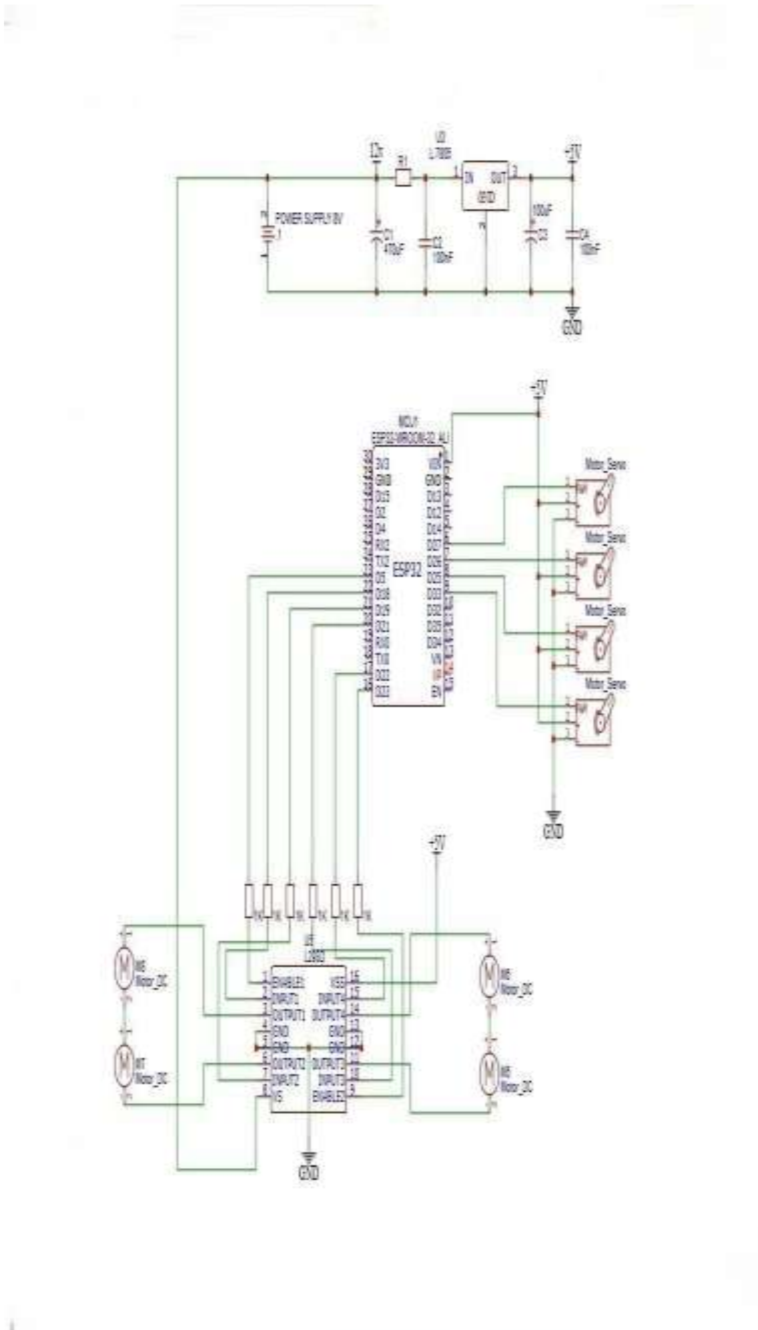
Robot movement is achieved using four 300 RPM gear motors, each controlled through an L293D motor driver. The L293D module amplifies the low-power control signals from the ESP32 to drive the gear motors, enabling directional movement—forward, reverse, left, and right—based on user input.

A servo motor-operated robotic arm is mounted on the robot for waste collection. This arm is designed to mimic basic human arm functionality to pick up lightweight waste materials and deposit them into the onboard dust bin. The servo motor's precision and controlled angular motion allow effective grasping and lifting actions. It is also controlled via an L293D motor driver, connected to the ESP32.

The system is powered by a centralized power supply unit, which delivers regulated voltage to the ESP32, L293D drivers, gear motors, and servo motor. Proper power distribution ensures reliable and safe operation of all components.

The web interface, designed using HTML and JavaScript, communicates with the ESP32 using HTTP requests. Each command sent via the interface corresponds to a specific action such as movement or arm positioning, giving the user full manual control of the robot in real time.

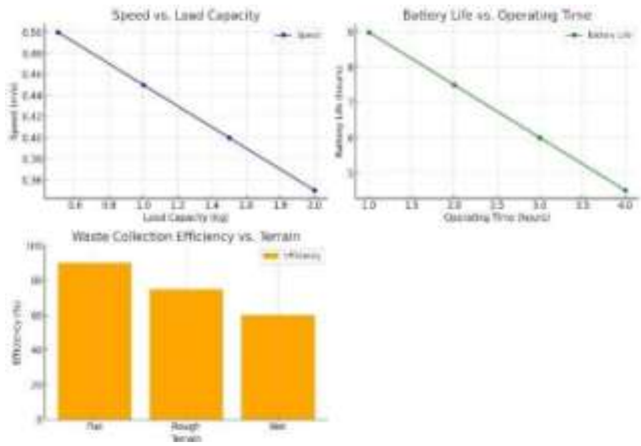
Circuit Diagram :



Result: To evaluate the performance of the solid waste collection robot, three key parameters were assessed: speed versus load capacity, battery life versus operating time, and efficiency on different terrain types. The graphical results of the experiments are presented and discussed below.

Speed vs. Load Capacity

The robot's speed exhibited a negative correlation with increasing load capacity. As observed in the plot, the speed decreased as the load increased. This decline is attributed to the added weight causing higher resistance, thereby demanding more torque from the motors and reducing overall from the motors and reducing overall movement speed.



Battery Life vs. Operating Time

The battery life diminished with prolonged operating durations. Initially, the robot had higher battery backup, which significantly reduced with continuous operation. This indicates that battery efficiency decreases with longer durations, likely due to increased energy demand from both the driving and waste collection mechanisms.

Waste Collection Efficiency vs. Terrain

Terrain type had a noticeable impact on the robot's collection efficiency. On flat terrain, the robot achieved the highest efficiency, whereas on rough terrain it dropped. The lowest efficiency was recorded on wet terrain. This trend highlights the influence of traction and motor performance on different surfaces, where slippage and navigation difficulty reduce effective collection.

CONCLUSION

The design and implementation of the web operated solid waste collection robot present a practical solution to the growing challenges of urban waste management. By integrating IoT through the ESP32-WROOM microcontroller, along with DC and servo motors, IR sensors, and a robotic arm, the system successfully enables remote operation, efficient navigation, and waste handling. The robot helps reduce direct human involvement in hazardous waste zones and promotes hygienic practices in public sanitation.

The project's successful execution demonstrates how cost-effective, scalable, and user-friendly technologies can be leveraged to support cleaner and smarter cities. While the robot currently operates through manual commands via a web interface, future improvements could include automation through AI-based object recognition and path planning. This work serves as a foundation for more advanced waste management systems that prioritize safety, efficiency, and sustainability.

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